FULL TITLE: Food intake and appetite following school-based high intensity interval training in 9-11-year-old children.

RUNNING TITLE: HIIT, energy intake and appetite.

KEY WORDS: High intensity interval training, appetite, food intake, children, physical education

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ABSTRACT

Using a randomised cross-over design, free-living lunch intake and subjective appetite were examined in 10 children (9.8±0.6 years) following high intensity interval training (HIIT) versus a control sedentary (SED) period, within a school setting. The 22 minute HIIT took place during a regular PE lesson and consisted of two rounds of 4 x 30 second sprints. Foods were offered at a regular school lunch immediately following HIIT and SED and were matched between conditions. All food was covertly weighed before and after the meal. Hunger, fullness and prospective consumption were reported immediately before and after HIIT/SED, using visual analogue scales. Heart rate was higher during HIIT than SED (159.3±23.1 v 76.9±2.2 bpm, $P<0.05$). Lunch energy intake was not different (***P*=0.52**) following HIIT, compared to SED (2.06±0.35 v 2.09±0.29 MJ, respectively). There were no significant differences in macronutrient intake or subjective appetite ($P>0.05$). Results suggest that HIIT can be implemented in a PE lesson immediately before lunch, without causing a compensatory increase in food consumption.

KEY WORDS: High intensity interval training, appetite, food intake, children, physical education

Introduction

During childhood and adolescence, children and young people establish behaviour patterns that have implications for immediate and long-term health and wellbeing (Parikh and Stratton, 2011). Furthermore, physical activity has been observed to offer protection against early onset of certain cardiovascular disease factors in young people themselves (Andersen, Riddoch, Kriemler, and Hills, 2011) as well as contributing to energy expenditure, and thus energy balance and obesity prevention (Janassen and LeBlanc, 2010). Despite these important factors, one in three 10-11-year-old children are classed as overweight or obese (Public Health England, 2014) and the majority of young people are not meeting physical activity recommendations (World Health Organisation, 2010). The most recent Health Survey for England data (HSE, 2012) states that only 21% of boys and 16% of girls were meeting current guidelines of at least one hour of moderate to vigorous intensity physical activity (MVPA) per day (Department of Health, 2011). Furthermore, physical activity is known to reduce with age for both sexes, and in their systematic review of 26 cross-sectional studies, Dumith, Gigante, Domingues, and Kohl (2011) reported annual physical activity losses of 7% per year potentially leading to a 60-70% decline throughout the entire adolescent period.

The school setting is well established as a vehicle for physical activity interventions (Kriemler et al., 2011), however evidence indicates that a challenge exists in achieving the recommended 50-80% of time active during a standard physical education (PE) lesson (Hollis et al, 2016; Racette et al. 2015; Association for Physical Education, 2015). Moreover, the tradition of competitive games emphasising the importance of skill development, strategies and tactics has meant that health benefits have been viewed as a by-product of PE rather than a central goal (Kirk, 2006). It is clear that alternative PE strategies need to be explored in order to optimise quality and quantity of MVPA in the school setting.

High intensity interval training (HIIT) is emerging as a new **form** of physical activity for young people (Logan, Harris, Duncan and Schofield, 2014), with potential to become a popular mode of exercise because it can be completed in a short duration of time, yet also effectively challenges the aerobic energy system (Corte de Araujo et al., 2012). Although it can be performed in a variety of ways, HIIT is usually defined as brief to moderate duration intervals of high intensity exercise, separated by short periods of low intensity or no physical activity (Laursen and Jenkins, 2002). The low intensity (active rest) or no physical activity (passive rest) periods allow for partial but not complete recovery. In children, this type of training has typically taken the form of **repeated** shuttle runs (Buchan *et al*., 2011).

Emerging HIIT evidence potentially challenges the recommendation that all children and young people should participate in at least 60 minutes of exercise per day in order to elicit cardiovascular health benefits (O'Donovan *et al.*, 2010). Indeed, findings suggest that significant improvements to various parameters of health and fitness can be achieved in substantially less time (Whyte, Gill, and Cathcart, 2010). Furthermore, HIIT appears to be more desirable to children and young people than does continuous aerobic exercise (Tjonna et al, 2009; Bartlett et al., 2011); certainly the intermittent, short duration, high intensity nature of HIIT replicates children's less structured spontaneous physical activity patterns (Tjonna *et al.*, 2009).

Despite attention on physical activity as a modifiable risk factor in young people (Janssen and LeBlanc, 2010; Mountjoy et al., 2011) the relationship between activity and food intake is often ignored. Any sustained imbalance between energy intake and expenditure will result either in loss of weight (Jequier and Tappy, 1999; Schwartz, 2012; Speakman, 2014), or attainment of a positive energy balance, ultimately leading to weight gain and obesity. Previous work has often involved controlled, laboratory-based protocols to manipulate and examine acute food intake responses to physical activity (Bozinovski et al., 2008; Dodd, Welsman, and Armstrong, 2008). Curriculum-based activity (netball) has also been examined (Rumbold et al., 2011; 2013) and recently screen-based physical activity and the impact on snack intake has been explored (Allsop et al., 2015; 2016). For the most part, little evidence exists to suggest ‘compensation’ for activity-induced energy expenditure; in other words, prescribed exercise bouts do not appear to result directly in an increase in energy intake, although some work does suggest a reduction in energy intake following exercise (Moore, Dodd, Welsman, and Armstrong, 2004; Thivel et al., 2016) and notably this has been observed with continuous cycling exercise at high intensity at 75% VO_2max (Thivel et al., 2012).

To date, despite a recent proliferation of literature attesting to the cardiovascular fitness and time-efficient benefits of HIIT for this population. only one study has examined the acute impact of HIIT-style activity on food intake and appetite in children. Crisp, Fournier, Licari, Braham, and Guelfi (2012) reported lower post-exercise energy intake in 11 8-12 year old boys following 4 second cycling sprints at 60 second intervals, compared to continuous moderate cycling. As is the case with much of the extant literature around activity and food intake in children, Crisp and colleagues (2012) manipulated physical activity and observed food intake using an ad libitum-style buffet in a laboratory setting. Considering HIIT-based activity in a school-setting may better reflect the natural or free-living habits of the children and might thus be considered in future study design.

The purpose of the present study was to determine the effects of a bout of HIIT delivered during a PE lesson, on food intake and appetite at a subsequent school lunch in 9-11-year-old children.

Methodology

Design

A within-subject, randomised cross-over design was used to compare food intake and appetite responses following a bout of HIIT, **versus equivalent rest (control),** for 10 children aged 9-11 years. The study took place over two days, with 1 week between each treatment day. The days were counterbalanced, containing a HIIT intervention (n=5) and equivalent sedentary (SED) period for the other five non-exercising participants. Conditions were reversed one week later so that all 10 children completed both HIIT and SED. The 22 minute HIIT/SED intervention took place during a 30 minute PE lesson immediately prior to a regular school lunch in the dining hall. Foods offered were matched between conditions and covertly weighed by the lead researcher before and after meals. Hunger, fullness and prospective consumption were reported immediately before and immediately following HIIT/SED, using visual analogue scales (VAS) (Moore, Dodd, Welsman, and Armstrong, 2004).

Participants

Five girls and five boys aged 9.8±0.6 years from a local primary school in North Yorkshire, England, participated in the study. Permission was given by the Head Teacher and participants were selected by the school to take part in the study as a reward for being Sports Leaders. Ethical approval was granted by the School of Applied Social Sciences Ethics Committee, Durham University. All parents and children received information sheets detailing the procedures, requirements and risks of the study and written informed consent was obtained from the child and parent or guardian prior to data collection. A pre-testing medical questionnaire was completed by all participants.

Population characteristics

Mean±SD mass was 38.9±10.1 kg, stature was1.45±1.01 m, waist circumference 63.4±5.9 cm and BMI 18.3±2.6 kg/m^2. Mean maturity offset was -0.48±0.72 and -0.54±0.70 years from peak height velocity years for girls and boys, respectively (Mirwald, Baxter-Jones, Bailey, and Beunen, 2002)

Preliminary measures

Parents and children were invited to a meeting at school where they were encouraged to ask any question or raise any concerns prior to commencement of preliminary testing. Children were familiarised with the HIIT protocol, weighed food diaries and

VAS. All anthropometric measurements were taken in triplicate following standard ISAK procedures (Marfell-Jones, Olds, Stewart, and Carter, 2007). Height (cm) was measured using a Harpenden Portable Stadiometer (Holtain Limited, Pembs, UK). Weight (kg) was measured using Avery Balance scales (Avery Berkel Ltd, West Midlands, UK) whilst participants were wearing light sports clothing and no shoes. Seated height was determined by measurement of height and seated height using a Harpenden Portable Stadiometer (Holtain Limited, Pembs, UK). Leg length was calculated as height minus seated height. Body mass index (BMI) was determined as weight (kg)/height (m^2). Waist circumference was measured using a Seca 203 ergonomic circumference measuring tape. Children assumed a relaxed standing position with arms folded across the thorax and the measurement was taken at the narrowest part of the waist, at the end of a normal expiration.

Procedures

The intervention (both HIIT and SED) was conducted during a 30 minute PE lesson in the school hall, immediately prior to the regular school lunch meal at 12:30pm. Children and parents were provided with a weighed food diary in which to record breakfast food and fluid intake on the first testing day. For standardisation, children (and parents) were then asked to replicate this breakfast intake on the second testing day (SED/HIIT) 1 week later.

High intensity interval training condition

The lead researcher led the session in the school hall, supported by the head teacher. The HIIT was 22 minutes in duration inclusive of warm up and cool down. The warm up consisted of 3-4 minutes light jogging followed by static and dynamic stretches. The cool down involved 3-4 minutes of light to very light jogging, followed by developmental and maintenance stretches.

High intensity interval training involves short periods of high intensity exercise, such as sprints, followed by intervals of little or no physical activity (Weston, Taylor, Batterham and Hopkins, 2014) and this general structure formed the foundation for the HIIT intervention in the present study. To date, studies implementing HIIT protocols with children are limited, however available protocols typically incorporate a shuttle runs consisting of intervals of maximum effort followed by short rest periods (Buchan et al., 2011, Taylor, Weston and Batterham, 2015). Our HIIT was adapted from those used by Buchan et al. (2011) and Taylor et al. (2015). The number of repetitions and the sprint duration was reduced to suit the younger participants. Sprint distance used by Buchan et al. (2011) was 20 metres however this was adapted to 17 metres because of the size of the school hall. Children were timed using a stop watch.

The course was marked out with cones over 17 m (to give the children direction for running and walking) and consisted of the following:

1. Thirty seconds all out running effort

2. Thirty seconds active rest (walking)

3. Steps 1 to 2 repeated three further times.

4. Passive rest lasting 4 minutes.

5. Stages 1-3 repeated once.

Sprints were described to the children as ‘maximum efforts’ and it was explained that they would feel out of breath, heart rate and breathing would increase and they would start to feel tired very quickly.

Sedentary condition

During the SED condition, children rested on benches in the school hall and observed the children taking part in HIIT. They were supervised by a member of the research team and were encouraged to verbally motivate the HIIT participants.

Exercise intensity

Heart rate was recorded every minute using Polar Heart rate monitors (Polar Electro, Oy, Finland). Children in both the HIIT and SED conditions were instructed not to touch buttons on the receivers, but to shout out their heart rate every minute. Mean heart rate was calculated from each 30 second bout.

Food intake

In order to replicate a free-living environment so far as possible, children were provided with an *ad libitum* meal in the form of a usual school dinner in the school dining hall after HIIT/SED and before the rest of the school entered the dining hall. There was a 5-10 minute turnaround between end of exercise and onset of food intake. All food was prepared in the school kitchen by the school’s cook. The school menu rotated day-to-day but remained the same week-to-week, therefore, all testing was conducted on a Thursday so as to ensure an identical lunch was offered between conditions. The meal consisted of breaded salmon, boiled potatoes, grated carrots and bread, followed by chocolate Rice Krispie cake, fruit and yoghurt. A vegetarian option of vegetable pasta bake was also offered but was not chosen by any of the children on either occasion. Water was available in jugs on the dining table. Children collected their food from the counter and received the standard meal portion provided by the school in agreement with guidelines provided by North Yorkshire County Caterers. When seated, the children were told that they could start eating at any point when they felt hungry, that they could consume as much or as little as they wanted and that they should collect more food from the counter as they desired until they felt comfortably full. All food was covertly weighed with kitchen scales (SALTER, UK) before and after meals by the lead researcher. Nutrient information was derived from food packaging and recipes provided by the school cook.

Appetite

Immediately pre- and post-HIIT and SED periods, children were asked to rate their hunger, fullness and desire to eat (prospective consumption) on three continuous 100 mm horizontal lines (Flint, Raben, Blundell, & Astrup, 2000). The response to the question ‘How hungry are you now?’ was anchored on the left by ‘Very hungry’ (100) and on the right by ‘Not at all’ (0). ‘How full do you feel?’ was anchored on the left by ‘Very full’ (100) and on the right by ‘Very empty’ (0). Prospective consumption, ‘How much could you eat right now?’ was anchored on the left by ‘Lots and lots’ (100) and on the right by ‘Nothing’ (0).

Statistical analysis

The statistical package IMB SPSS Statistics 20 (SPSS Inc., Chicago, IL) was used for data analyses. Paired samples t-tests were used to compare heart rate, energy and macronutrient intake between HIIT and sedentary conditions. Effect size (*r*) was calculated according to Cohen's *d* and effect size magnitude was classified as: trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (≥0.80) (Cohen, 1992). Confidence intervals (95%) were also calculated. Repeated measures ANOVA (exercise condition x time) were performed for each of hunger, fullness, and prospective consumption. Effect size was calculated using partial Eta squared (η_p^2) with $0.01<\eta^2 < 0.06$ defined as a small effect, $0.06< \eta^2 < 0.14$ a medium effect and $\eta^2 >0.14$ a large effect according to Cohen (1988). An alpha level of $P<0.05$ determined significance.

Results

Heart rate

As shown in figure 1 mean heart rate was higher during the 22 minute HIIT than in the corresponding SED period (159.3±23.1 v 76.9±2.2 bpm, $P<0.001$; effect size: 0.93 and 95% CI: 66.61 to 98.14).

Energy and macronutrient intake

None of the children actually consumed all of the food served to them following HIIT (compared to two of the 10 children consuming all foods following SED), so a ceiling effect was unlikely. School lunch energy intake (figure 2) was not significantly different (P=0.52) for HIIT, compared to SED (2.06±0.35 v 2.09±0.29 MJ, respectively; effect size: 0.05 and 95% CI: -0.13 to 0.07). There were no significant differences in macronutrient intake between conditions (P>0.05, see table 1.).

Appetite

No exercise condition (HIIT v SED) main effects were seen for hunger (P>0.05), fullness (P>0.05) or prospective consumption (P>0.05), although there was a 'time' (pre- v post) main effect for prospective consumption (P=0.002, η_p^2 = 0.67). As shown in table 2, there were no significant interaction effects for hunger (P=0.85, η_p^2=0.004), fullness (P=0.66, η_p^2=0.02), or prospective consumption (P=0.98, η_p^2=0.000).

Discussion

The present study was the first to assess food intake and appetite of children immediately following a HIIT-based PE lesson. The main finding from the present study was that despite a significantly higher heart rate in the HIIT condition, there was no evidence of any altered food intake at a subsequent lunch. Previous studies in young people have found a similar lack of short-term compensation for exercise across a range of activity simulations (Moore *et al.,* 2004; Dodd *et al.,* 2008; Rumbold *et al.*, 2011; Allsop *et al.,* 2015) although none of this work was HIIT-based or in a regular free-living school lesson and meal environment.

The HIIT session was successful at eliciting heart rate substantially above resting levels, when compared to SED. This increase in heart rate demonstrates the ability of the prescribed HIIT intervention to successfully elevate intensity in a short amount of time, thus increasing energy expenditure and demonstrating the potential for inducement of a negative energy balance.

No significant difference was found for energy or macronutrient intake between the HIIT and SED conditions. This is contrary to a popular belief that exercise will evoke an immediate increase in hunger (Mayer, Roy, and Mitra, 1956). In their recent systematic review of energy and macronutrient intake in youths, Thivel and colleagues (2016) reported that of 14 included studies representing a total of 31 different exercise sessions, 23 found no change in energy consumption, one found an increase and seven actually observed a reduction in EI. It is also clear from this review that there is huge variability in terms of exercise duration, modality, intensity and participant age within this relatively small body of work to date. This of course makes it hard to draw firm conclusions in terms of what is effective and for whom, however it is worth exploring findings from some of the work most comparable to the present study.

In 9-10-year-old girls, a reduction was seen in lunch intake following laboratory-based cycling exercise at 50% VO_{2max} (Moore et al., 2004) although exercise was conducted in 10-15 minute bouts, lasted much longer (56 minutes) than that in the present study and was of lower intensity. Thivel and colleagues (2012) also reported a reduction post-exercise food intake both at lunch and dinner for 15 obese adolescent boys, but following 30 minutes of high intensity laboratory-based cycling at 75% $VO_{2max.}$ Conversely, using a similar 75% VO_{2max} cycling protocol (38 minutes), Moore and colleagues (2004) saw no alteration in lunch energy intake, a finding similar to a number of other studies of similar duration, mode and intensity in older children (Thivel et al., 2016).

Short-duration exercise bouts have been implemented in other work, although not in the same age group or using a similar mode or intensity of exercise. For example, Bozinovski et al (2009) reported no effect on energy consumed from a pizza meal offered 30 minutes following short-duration treadmill running (15 minutes, compared to no exercise or longer-duration exercise) in 9-14 year olds, although the intensity of the exercise was lower than that of the present study and there was a greater gap between exercise termination and provision of food than that in the present study. Most comparable perhaps are the findings of Crisp and colleagues (2012) who offered food in a buffet meal 5-10 minutes after exercise termination in 8-12 year old overweight boys. Although not using a work-to-rest format typical of HIIT, nor a rest condition for comparison, noteworthy is that acute energy intake following 30 minutes of moderate continuous cycling was similar to energy intake following the same continuous cycling but with 4 second sprints interspersed every 30 or 120 seconds. Interestingly relatively lower energy intake was observed where sprints were every 60 seconds. Our findings also compare favourably with those of Corte de Araujo et al (2012) who actually examined food intake following 12 weeks of treadmill-based HIIT in 8-12-year-old children. This study differed to ours as they did not examine acute responses to exercise, and the group were classed as obese, however they reported a reduction in BMI without any change in energy or macronutrient intake over the 12 weeks. Our findings from a naturalistic trial add to the small evidence base and support the notion that the energy expended from HIIT might be sufficient to attenuate energy balance without inducing a corresponding increase in energy intake.

It is useful to consider the amount of energy consumed at the lunch meal in terms of representing a 'usual intake' for this group. The UK National Diet and Nutrition Survey (2014) reported mean daily intakes of 6.46 MJ for 4-10-year-old children. Furthermore, UK dietary reference values for this age group state that a total daily intake of 7.2 MJ (girls) and 7.7 MJ (boys) is appropriate for health (SACN, 2011). Observed lunch intakes of 2.06±0.35 v 2.09±0.29 MJ in the present study therefore represent just under a third of reported daily intake in 9-year-old UK children, which is sensible for a lunch meal.

The present study found a lack of exercise-induced change in subjective appetite rated immediately post exercise or SED, with no differences reported between HIIT and SED for any of hunger, prospective consumption or fullness. Dodd et al. (2008) noted increased sensations of hunger in similar age overweight girls, following cycling at 75% VO_{2max}, and this was also observed by Rumbold et al. (2011) in older trained netball players. Contrasting findings have been reported, however, for example in lean girls where appetite was largely unaltered following the same exercise challenge (Dodd et al., 2008; Moore *et al.*, 2004). Again, a range of exercise modalities, duration, intensities and ages within the existing body of evidence impacts upon firm conclusions being drawn.

Bozinovski and colleagues (2009) postulated that before lunchtime might be a useful time to implement exercise in children. Indeed, this group reported attenuated self-reported hunger, desire to eat and average appetite following short-duration (15 minutes) of treadmill walking, compared to rest, in 9-14-year-old children. We would agree with this assertion and suggest that this extends to higher intensity activities that realistically could be conducted within the setting of a school PE lesson, for example HIIT. If HIIT does not attenuate, then neither does it appear to increase sensations of appetite in this particular group of children; this is positive when considering health outcomes such as the drive for food intake and ultimately, the potential for disruptions to energy balance. Further work might examine longer-term habitual appetite parameters during the school week and consider the positioning of exercise and meal times.

Given the variability in participant characteristics within this field of work, we attempted to measure and describe these as robustly as possible. Weight status was determined according to recommended BMI cut off points (Cole, Freeman and Preece, 1995). Mean BMI of the group was 18.3±2.6 kg/m^2 which is classified as a 'healthy weight' (5th percentile). Mean waist circumference of the group was 63.4±5.9 cm. Considering waist circumference percentiles, mean waist circumference of the children in our study was between the 75th and 90th percentiles, indicating no increased risk of overweight or obesity (McCarthy, Jarrett, and Crawley, 2001).

We suggest that a strength of the present study is the effort to control for maturation stage, rather than rely on just chronological age to describe the cohort. Mean predicted years from average peak height velocity was calculated according to Mirwald et al. (2002). Maturity offset was -0.5±0.7 years from age of peak height velocity, implying that the participants in this group were pre-pubertal.

We acknowledge the small sample size as a limitation in this study and appreciate that results cannot necessarily be generalised to the wider population without further work in this area. A further limitation is the lack of measurement of water intake during lunch.

Conclusion

In 9-11-year-old children, a HIIT-based PE lesson did not evoke any change in food intake or appetite at a lunch meal offered immediately afterwards. We consider that the naturalistic study design increases the ecological validity of our findings, providing a practical application through which to potentially increase physical activity in school children throughout the school day. Further work should explore sustainability of HIIT as part of the PE curriculum. Clearly there is potential for this kind of activity to contribute to manipulation of energy regulation during the school day, and as such we recommend that longer-term food intake, energy balance and appetite should be explored in future studies.

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Table 1. Mean ± SD macronutrient intake (g) following the high intensity interval training (HIIT) and corresponding sedentary (SED) condition.

Macronutrient Intake	HIIT	SED	Confidence Interval	Effect Size	*P* Value
Fat (g)	22.9±3.7	23.4±3.2	-1.25, 0.34	0.07	0.227
CHO (g)	58.4±11.6	60.2±9.5	-5.21, 1.57	0.08	0.256
Protein (g)	12.5±1.5	12.7±1.2	-0.64, 0.36	0.07	0.554

Table 2. Mean ± SD ratings of hunger, fullness and desire to eat (mm) immediately before (pre) and immediately after (post) the high intensity interval training (HIIT) and corresponding sedentary (SED) condition.

	Hunger (Very hungry=100)		**Fullness (Very full=100)**		**Prospective Consumption (Could eat lots and lots=100)**	
	HIIT	**SED**	**HIIT**	**SED**	**HIIT**	**SED**
Pre	40.2±26	33.9±23	44.3±26	44.3±22	46.7±31	40.7±24
Post	52.7±31	43.2±20	43.3±26	37.4±19	58.1±29	52.3±23

No significant interactions were found ($P > 0.05$).

Figure captions

Figure 1. Mean ± SD heart rate (bpm) during the high intensity interval training (HIIT) and corresponding sedentary (SED) conditions. *Different to SED ($P < 0.01$).

Figure 2. Mean ± SD energy intake (MJ) following the high intensity interval training (HIIT) compared to the matched sedentary (SED) condition ($P > 0.05$).

Figure 1.

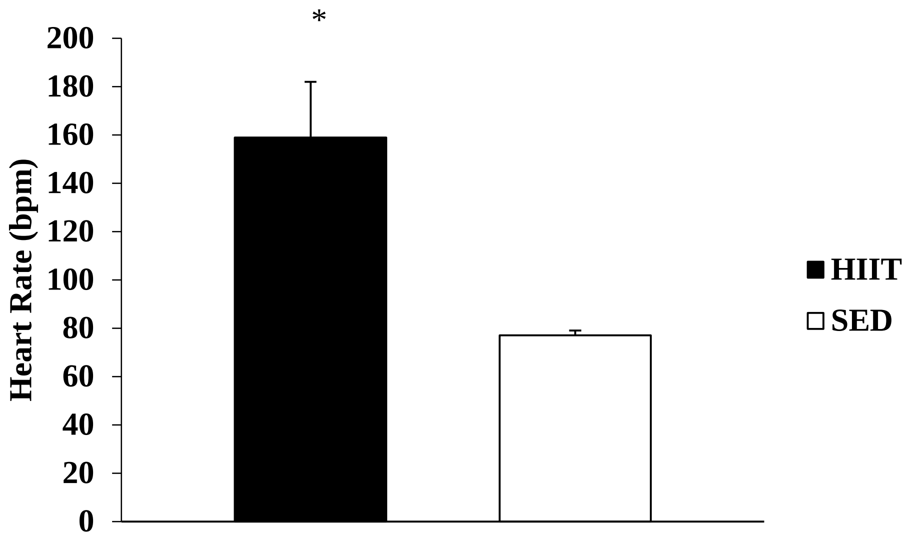

Figure 2.